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September 2015

Joseph Lstiburek

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES OFFICE

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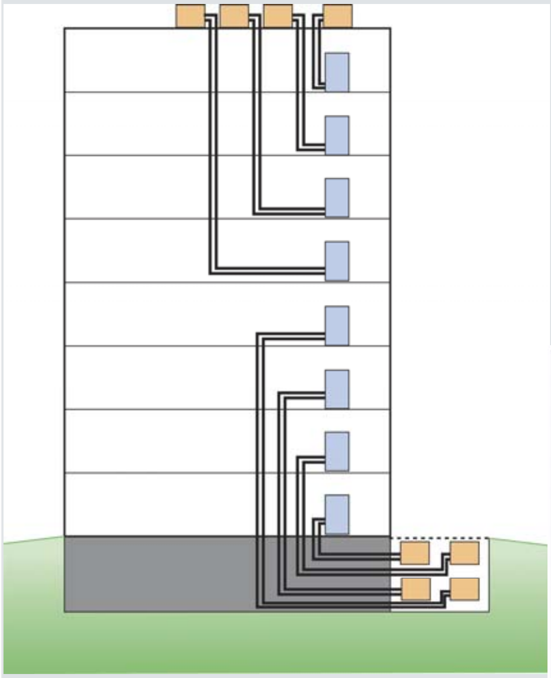

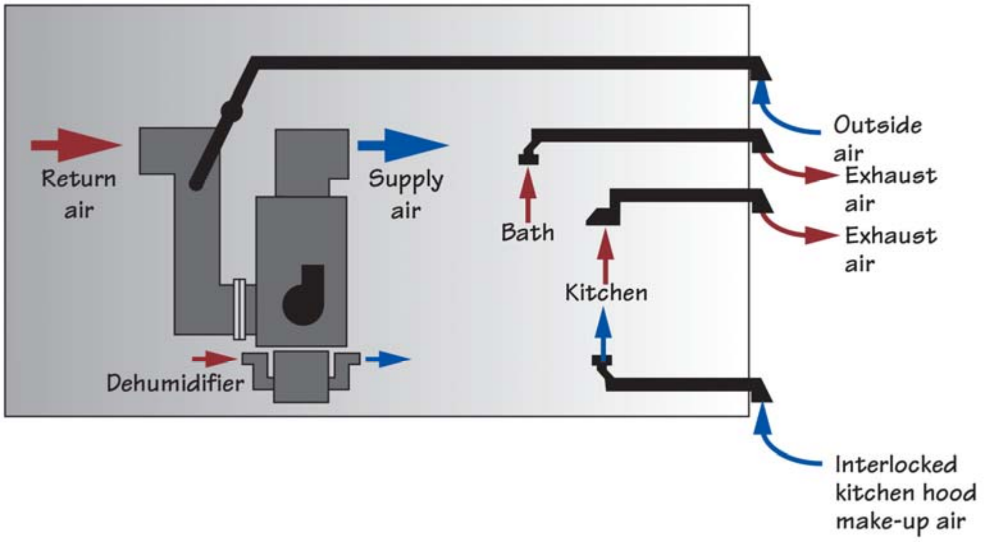

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Prepared for:

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Office of Energy Efficiency and Renewable Energy

15013 Denver West Parkway

Golden, CO 80401

NREL Contract No. DE-AC36-08GO28308

Prepared by:

Joseph Lstiburek, Ph.D., P.Eng.

Building Science Corporation

3 Lan Drive, Suite 102

Westford, MA 01886

NREL Technical Monitor: Stacey Rothgeb

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The laboratory and/or field sites used for this work are not certified rating test facilities. The conditions and methods under which products were characterized for this work differ from standard rating conditions, as described.

Because the methods and conditions differ, the reported results are not comparable to rated product performance and should only be used to estimate performance under the measured conditions.

Contents

List of Figures

Unless otherwise noted, all figures were created by Building Science Corporation.

Definitions

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BA	Building America Program
BSC	Building Science Corporation
DOE	U.S. Department of Energy
HVAC	Heating, ventilation, and air conditioning
IBC	International Building Code
ICC	International Code Council
IRC	International Residential Code for One- and Two-Family Dwellings
NREL	National Renewable Energy Laboratory

Abstract

The measure guideline provides ventilation guidance for residential high performance multifamily construction that incorporates the requirements of the ASHRAE 62.2 2013 standard. The measure guideline focus is on the decision criteria for weighing cost and performance of various ventilation systems.

The measure guideline is intended for contractors, builders, developers, designers and building code officials. The guide may also be helpful to building owners wishing to learn more about ventilation strategies available for their buildings.

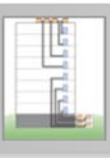
The measure guideline includes specific design and installation instructions for the most cost effective and performance effective solutions for ventilation in multifamily units that satisfies the requirements of ASHRAE 62.2 2013.

Progression Summary

MULTIFAMILY VENTILATION

The following outlines the steps to consider when designing and installing multifamily ventilation systems.

IDENTIFY GOALS

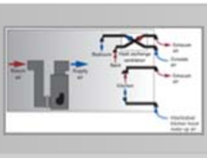


1 **Identify project goals**. Develop project goals with consideration given to health and safety, climate zone, energy performance and cost, and any other project-specific criteria or constraints.

REVIEW CODES

2 **Review building code requirements**. Review the locally adopted building code for health and safety, fire, and minimum energy performance requirements.

DESIGN



3 **Design**. Decide on the ventilation system best suited to the project goals that will be required to implement the design.

CONSTRUCTION

4 **Construction**. Plan the installation process, including sequencing. For moderate to large projects, consider engaging a qualified engineer to design the system.

1 Introduction

Building America requires that single-family and multifamily buildings are compliant with ASHRAE Standard 62.2 – 2013. The standard has undergone significant changes since first being issued in 2003. One of the most significant is an increase in ventilation rates – almost a doubling of the ventilation requirements for a 1,000 ft2 multifamily unit (from 25 cfm to 45 cfm). Additionally, ASHRAE Standard 62.2 has a requirement for kitchen exhaust of 100 cfm.

The ICC 2015 International Residential Code (IRC) requires building enclosures to meet an air tightness performance metric of 3 ach@50 Pa or less. The IRC does not distinguish between single-family detached construction and multifamily construction. ASHRAE Standard 62.2 – 2013 as amended by Addendum E, requires an air tightness performance metric for multifamily units of less than 0.3 cfm per ft2 of the dwelling unit envelope area at a test pressure of 50 Pa. Both of these metrics result in enclosure tightness that is significantly more than current typical single-family detached construction but typical of high performance single-family detached construction (Finch et. al. 2009; Maxwell et. al. 2014) and typical of individual unit multifamily construction that meet model code fire and smoke control requirements and inter unit acoustical control requirements (Lstiburek 2005).

ASHRAE Standard 62.2 – 2013 also requires a continuous ventilation rate of 45 cfm for a one-bedroom enclosure of less than 1,000 ft2 floor area. No credit for infiltration is allowed for multifamily units. Additionally, ASHRAE Standard 62.2 – 2013 requires a vented kitchen range hood with a minimum intermittant exhaust flow of 100 cfm – or local kitchen area intermittant ventilation of 5 ach.

Exhaust-only ventilation at the ASHRAE Standard 62.2 – 2013 rate leads to significant depressurization in units that are constructed to meet the 2015 IRC or ASHRAE Standard 62.2 – 2013 air tightness requirements (CMHC 2005; Lstiburek 2013) and pulls air from neighboring units and corridors. Exhaust-only ventilation is not a viable ventilation strategy for multifamily construction. Nor is exhaust-only ventilation with passive air inlets.

Supply-only ventilation for multifamily construction at the ASHRAE Standard 62.2-2013 rates leads to significant pressurization of units. This has the unintended consequence of driving air into neighboring units and the resulting potential of odor and contaminant transfer.

Only balanced ventilation strategies are viable for multifamily construction and effective for high performance multifamily construction. Additionally, exhaust vented kitchen range hoods in multifamily construction are only effective with interlocked powered make-up air. Local kitchen area ventilation of 5 ach is proving problematic as no definition of “local” has been provided that is enforceable.

In warm-humid climates supplemental dehumidification is necessary in energy efficient homes where the sensible cooling load has been dramatically reduced (Rudd 2013). The issue is particularly acute in multifamily units ventilated at high ventilation rates such as those required by ASHRAE Standard 62.2 – 2013.

These are significant changes to current practice and this measure guideline addresses these issues.

2 Decision-Making Criteria

2.1 Advantages, Disadvantages and Costs

Each of the ventilation system options presented in this measure guideline has advantages, disadvantages and costs. In almost all cases the advantages, disadvantages and costs are subjective not objective after minimum requirements are met.

For example the choice of supplemental dehumidification is made by climate location. It is the only viable option in hot-humid and mixed-humid climates. No air conditioning systems currently exist that have sufficient dehumidification capability for multifamily units ventilated at ASHRAE Standard 62.2 – 2013 rates. Separate systems are required.

The choice of forced air vs. radiant is typically a regional choice. Radiant heating with no cooling is a Pacific Northwest approach to multifamily unit space conditioning. One method of providing balanced ventilation in such units is with an HRV or an ERV. Balanced ventilation system units are commercially available without heat recovery or energy recovery. The advantage of heat recovery or energy recovery is the higher energy performance.

In cases where a forced air system with air conditioning is compared with packaged terminal heat pumps (PTHP) little agreement exists. The cost of a ducted forced air system with outside air connected to the return side of the air handler coupled to an exhaust system in the bathroom(s) is similar to a ducted heat recovery ventilator (HRV) or energy recovery ventilator (ERV) providing the balanced ventilation with a PTHP. One has heat recovery/energy recovery and the other does not. It can be argued that since the costs are similar the HRV/ERV has an advantage due to the obvious energy savings. The counter argument is that maintenance and durability issues with a more complex system, such as an HRV/ERV, are not worth the energy advantage and the forced air system coupled to an exhaust system is viewed by others as preferable due to lower cost and less ductwork.

Where forced air systems are preferred by the marketplace (typically a regional bias) a stand alone HRV/ERV that does not interact with the forced air systems is viewed by some as a less complicated system to install and maintain than integrating the ventilation system with the forced air system.

2.2 Impact of Codes and ASHRAE Standard 62.2 on Multifamily Construction

The ICC 2015 International Residential Code (IRC) requires building enclosures to meet an air tightness performance metric of 3 ach@50 Pa or less. ASHRAE Standard 62.2 – 2013 as amended by Addendum E, requires an air tightness performance metric for multifamily units of less than 0.3 cfm per ft2 of the dwelling unit envelope area at a test pressure of 50 Pa. The 0.3 cfm per ft2 value was proposed by Lstiburek (2005).

This level of enclosure tightness is significantly more than current typical single-family detached construction but typical of high performance single-family detached construction (Finch et. al. 2009; Maxwell et. al. 2014) and typical of individual unit multifamily construction that meet model code fire and smoke control requirements and inter unit acoustical control requirements (Lstiburek 2005).

ASHRAE Standard 62.2 – 2013 also requires a continuous ventilation rate of 45 cfm for a one-bedroom enclosure of less than 1,000 ft2 floor area. No credit for infiltration is allowed for multifamily units. Additionally, ASHRAE Standard 62.2 – 2013 requires a vented kitchen range hood with a minimum intermittant exhaust flow of 100 cfm – or local kitchen area intermittant ventilation of 5 ach. Bathroom exhaust is also required at an intermittent rate of 50 cfm or a continuous rate of 20 cfm.

Exhaust-only ventilation at the ASHRAE Standard 62.2 – 2013 rate leads to significant depressurization in units that are constructed to meet the 2015 IRC or ASHRAE Standard 62.2 – 2013 air tightness requirements (CMHC 2005; Lstiburek 2013) and pulls air from neighboring units and corridors. Exhaust-only ventilation is not a viable ventilation strategy for multifamily construction. Nor is exhaust-only ventilation with passive air inlets (Maxwell et. al. 2014).

Supply-only ventilation for multifamily units at the ASHRAE Standard 62.2-2013 rate leads to significant pressurization of units. This has the unintended consequence of driving air into neighboring units and the resulting potential of odor and contaminant transfer.

Only balanced ventilation strategies are viable for multifamily construction and effective for high perfomance multifamily construction (Figure 1). Additionally, exhaust vented kitchen range hoods in multifamily construction are only effective with interlocked powered make-up air. Local kitchen area ventilation of 5 ach is proving problematic as no definition of “local” has been provided that is enforceable.

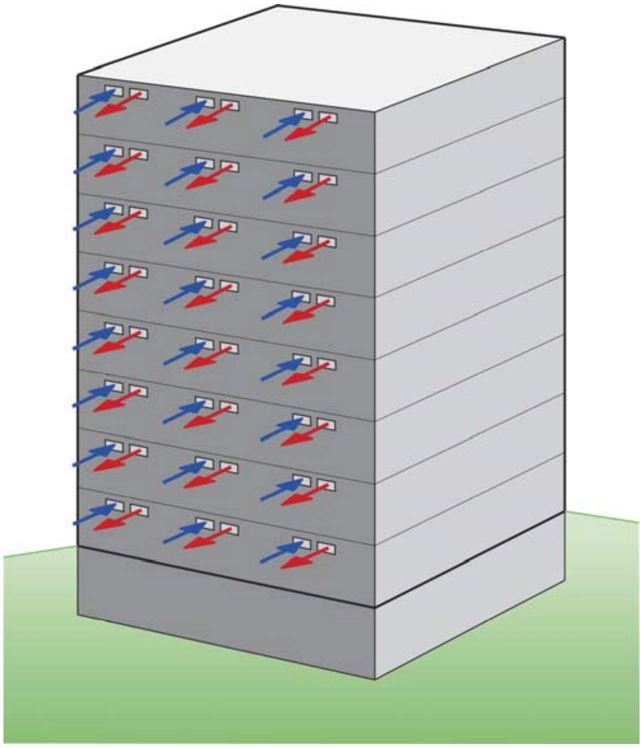


Figure 1: Balanced ventilation - Only balanced ventilation strategies are viable for multifamily construction

Installation of clothes dryers that are vented to the exterior also leads to significant depressurization in multifamily units. Clothes dryer exhaust rates are typically 200 cfm or more. Interlocked powered make-up air is necessary or alternatively unvented condensing clothes dryers must be used.

Intermittent bathroom exhaust at 50 cfm in multifamily units is also not possible without provision for make-up air.

In warm-humid climates supplemental dehumidification is necessary in energy efficient homes where the sensible cooling load has been dramatically reduced (Rudd 2013). The issue is particularly acute in multifamily units ventilated at high ventilation rates such as those required by ASHRAE Standard 62.2 – 2013.

2.3 Air tightness

High degrees of enclosure air tightness and unit compartmentalization are code required and a fundamental component of high performance construction. Acceptable indoor air quality is also a fundamental component of high performance construction. Ventilation approaches that are compliant with ASHRAE Standard 62.2 – 2013 within enclosures constructed in accordance with the ICC 2015 International Residential Code (IRC) currently are not typical.

3 Technical Description

3.1 Purpose of Ventilation

Ventilation is one component of an integrated approach to provide acceptable indoor air quality (IAQ) in buildings that includes source control of contaminants and environmental separation (the “building or unit enclosure”). Acceptable indoor air quality includes control of temperature and odors. Ventilation is the intentional movement of air from the outside of a building to the inside.

3.2 Uniqueness of Multifamily Construction

Multifamily units share common surface areas with neighboring units (Figure 2). Ventilation air should not be pulled from neighboring units for fire and smoke control reasons, for odor control reasons and for general IAQ reasons.

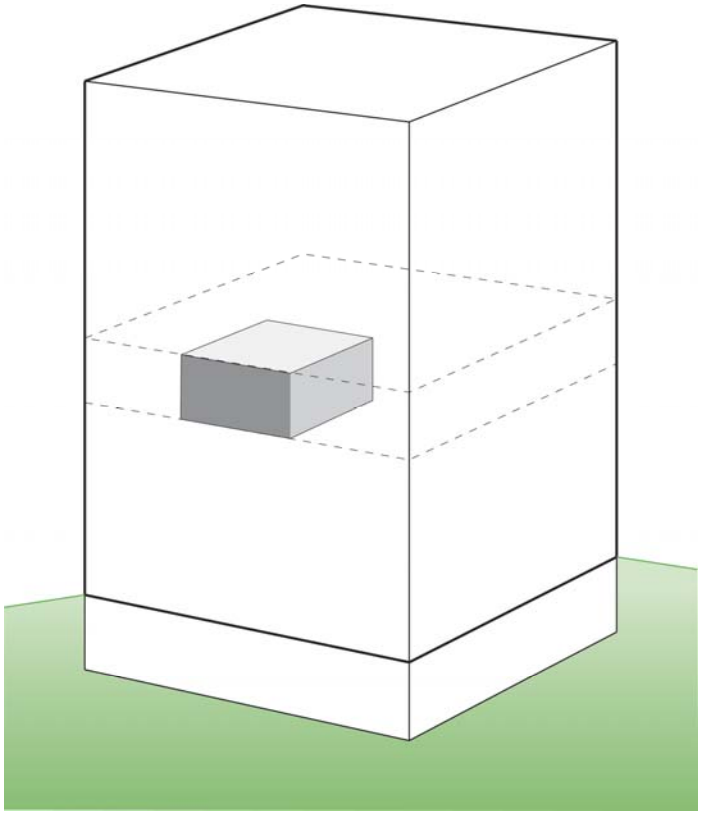


Figure 2: Multifamily construction – Multifamily units share common surface areas with neighboring units. Ventilation air cannot be pulled from neighboring units for fire and smoke control reasons, for odor control reasons and for general IAQ reasons

To prevent air from transferring between multifamily units high levels of air tightness are required as is the control of air pressure differentials. Common walls are also required to meet fire and smoke assembly requirements (Figure 3). Most floor assemblies in multifamily frame construction are sound proofed and fire proofed with liquid gypsum subflooring (Figure 4) that results in airtight wall assemblies at floor to wall connections.

Figure 3: Common wall construction – Common walls are required to meet fire and smoke assembly requirements

Figure 4: Floor assembly air sealing - Floor assemblies that are sound proofed and fire proofed with liquid gypsum subflooring result in airtight wall assemblies at floor to wall connections

Ventilation air is prohibited by model codes from being introduced into multifamily units from corridors. Multifamily unit to corridor doors are typically weather-stripped (Figure 5).

Figure 5: Weather-stripped corridor doors - Ventilation air is prohibited from being introduced into multifamily units from corridors; multifamily unit to corridor doors are typically weather-stripped

Ventilation air can only be introduced into multifamily units through infiltration through exterior walls or directly into the units by ducted supply or passive air inlets (holes in the exterior walls (Figure 6)) or slotted vents in windows.

Figure 6: Passive air inlet - Ventilation air can only be introduced into multifamily units through infiltration through exterior walls or directly into the units by ducted supply or passive air inlets - holes in the exterior walls

In multi-story construction stack effect driven airflows in buildings compromise smoke control and fire safety, adversely affect indoor air quality and comfort as well as increase operating costs for space conditioning energy (Figure 7). The air in lower units ends up in the upper units (Figure 8).

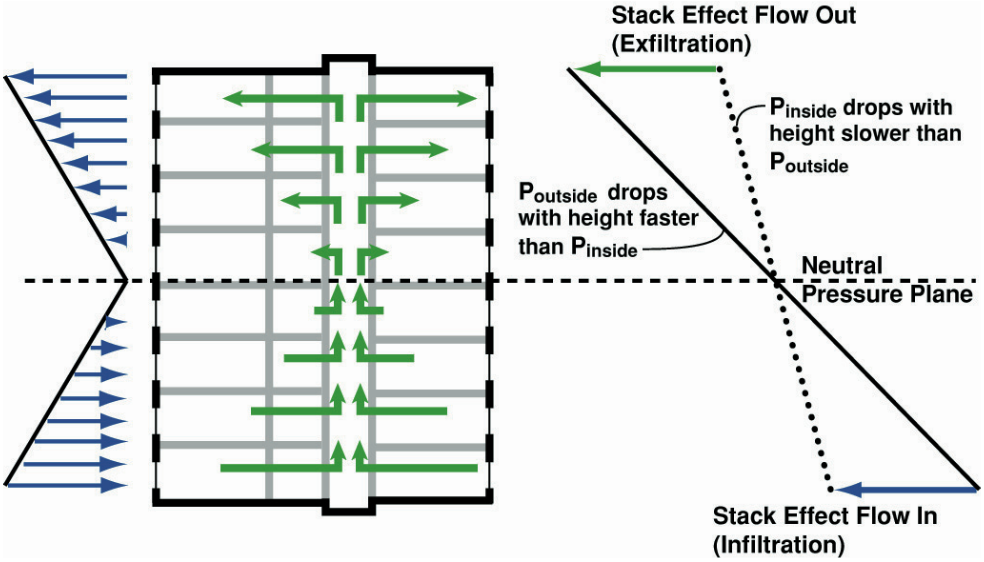


Figure 7: Stack effect in a multi-story building - Stack effect driven airflows in multi-story buildings compromise smoke control and fire safety, adversely affect indoor air quality and comfort as well as increase operating costs for space conditioning energy

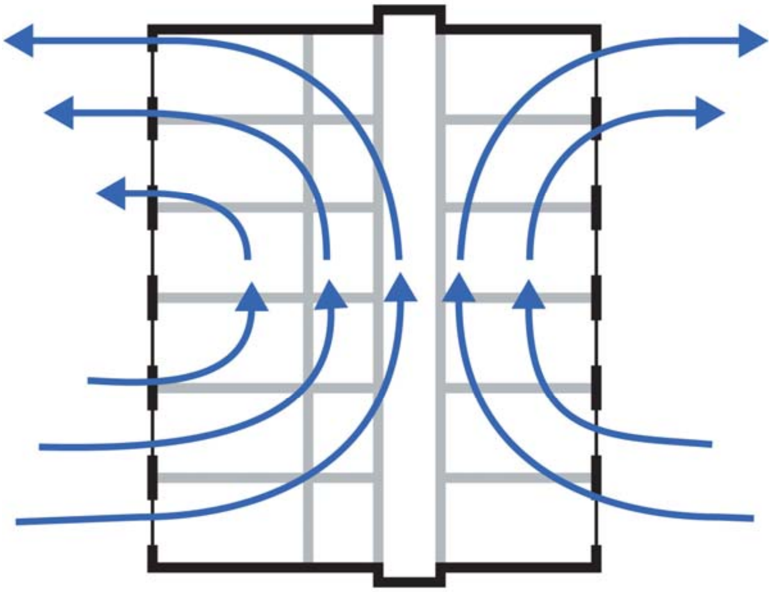


Figure 8: Stack effect driven airflow - The air in lower units ends up in the upper units

By isolating the units from each other and from corridors, shafts, elevators and stairwells stack effect driven interior airflows can be controlled (Figure 9). This is referred to as compartmentalization (Lstiburek 2005). The most elegant argument for compartmentalization of multi-story buildings comes from Handegord (2001). Lower units should not supply air to upper units.

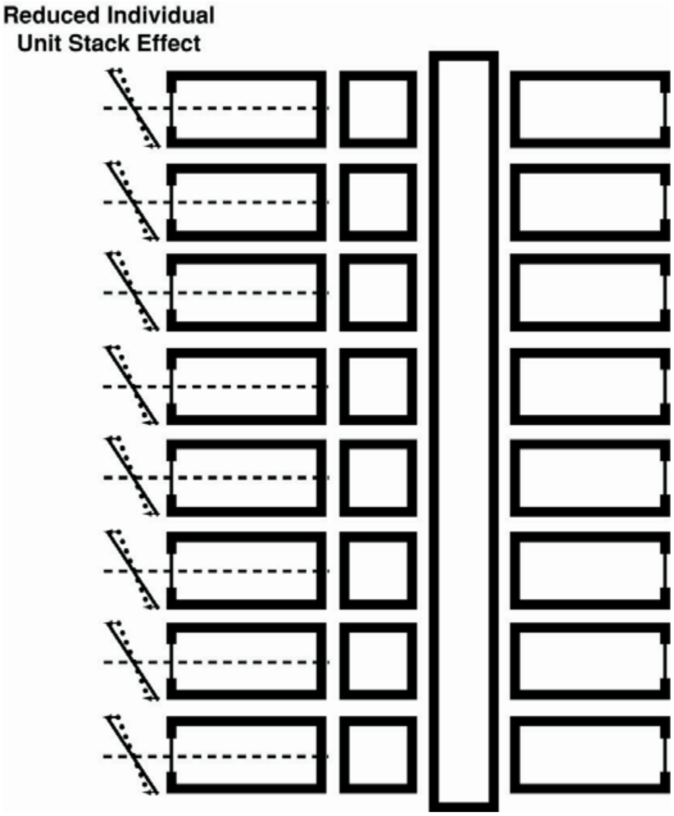


Figure 9: Compartmentalization - Basically, you turn a ten story building into ten one story buildings that are stacked on top of one another; by isolating the units from each other and from corridors, shafts, elevators and stairwells stack effect driven interior airflows can be controlled

Central systems that move air between units and floors for ventilation purposes result in multifamily units that do not meet compartmentalization air tightness requirements. Only distributed balanced ventilation systems work.

3.3 Ventilation System Options

Each system presented in this measure guideline is balanced and has provision for powered make-up air for vented kitchen range hoods and bathroom exhaust. Each system is designed to operate in a compartmentalized multifamily unit and with distributed heating and cooling systems (Figure 10, Figure 11, Figure 12 and Figure 13) or central systems where only hot water or chilled water or refrigerant is distributed, not air.

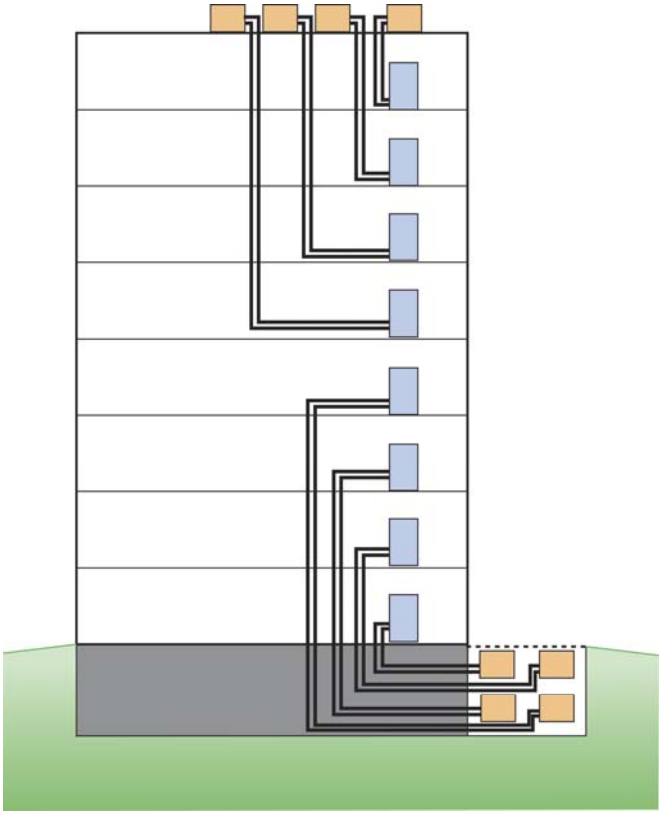


Figure 10: Distributed heating and cooling systems – Each unit is conditioned individually

Figure 11: Distributed heating and cooling systems – Each unit is conditioned individually

Figure 12: Individual supply and exhaust openings – Multiple exhaust grilles and supply grilles are required

Figure 13: Individual unit space conditioning – Each unit has its own air distribution system

Electric water heaters (Figure 14) do not need to be vented to the exterior whereas gas water heaters do. Gas water heaters if used should be sealed combustion two-pipe systems vented directly to the exterior with combustion air ducted directly to the water heater (Figure 15). Similarly, gas furnaces if used should be sealed combustion two-pipe systems.

Figure 14: Electric water heater - Electric water heaters do not need to be vented to the exterior whereas gas water heaters do

Figure 15: Gas water heater - Gas water heaters if used should be sealed combustion two-pipe systems vented directly to the exterior with combustion air ducted directly to the water heater

Where clothes dryers are installed they should be unvented condensing units (Figure 16) – or if vented to the exterior a provision for powered make-up air must be provided.

Figure 16: Clothes dryers - Where clothes dryers are installed they should be unvented condensing units – or if vented to the exterior a provision for powered make-up air must be provided

The ventilation efficiency of kitchen range hoods is determined by the size of the hood. The larger the hood compared to the cooking surface the higher the capture efficiency of the contaminant plume. It is recommended that make-up air be introduced below the cooking surface and that the range hood be wider and deeper than the cooking surface (Figure 17). Where this approach is used the volume flow rate of kitchen range hood exhaust can be reduced (ASHRAE 2011).

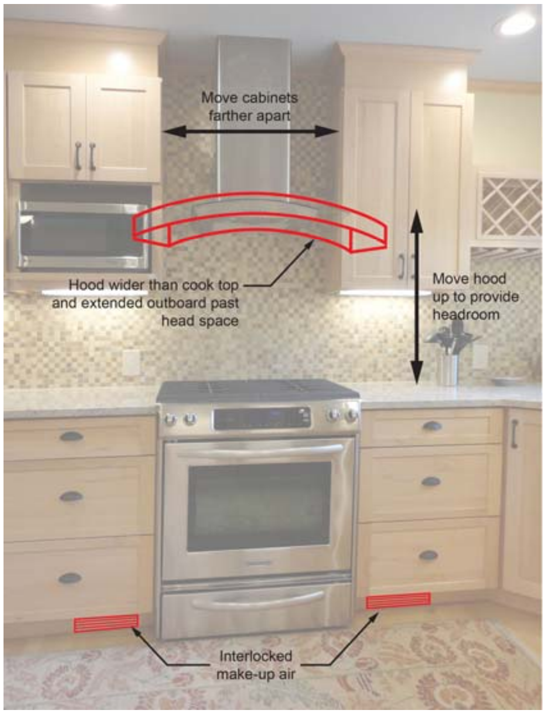


Figure 17: Kitchen range hood - It is recommended that make-up air be introduced below the cooking surface and that the range hood be wider and deeper than the cooking surface

In hot-humid climates and mixed-humid climates part load humidity cannot be controlled without supplemental dehumidification (Rudd 2013). This can be accomplished with stand-alone dehumidifiers (Figure 18, Figure 19, Figure 20 and Figure 21).

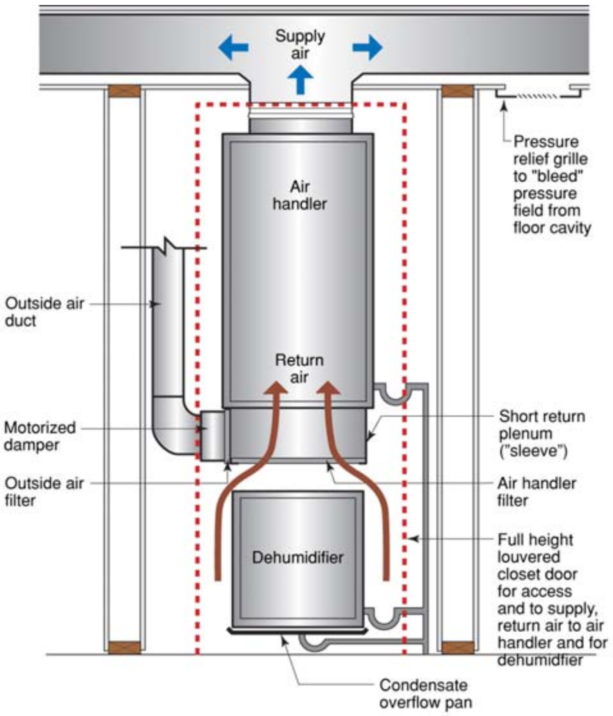


Figure 18: Dehumidifier – In return closet of forced air system

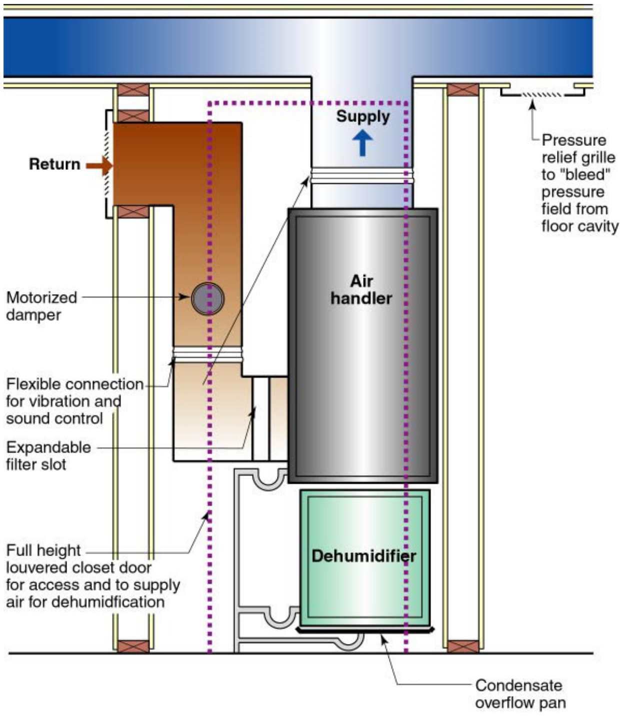


Figure 19: Dehumidifier – In ducted return system

Figure 20: Dehumidifier – Located in return closet

Figure 21: Dehumidifier – Located in closet with louvered door

3.4 Corridors, Elevator Shafts and Trash Chutes

When multifamily compartmentalization is executed the corridors and elevator shafts are ventilated independently as are trash chutes.

Corridors are required to be ventilated according to ASHRAE Standard 62.1 – 2013. ASHRAE Standard 62.2 does not have jurisdiction for corridors – just the individual multifamily units. Additionally, elevator shafts are governed by the International Mechanical Code.

The amount of ventilation required for a typical corridor is rather small – on the order of 20 or 30 cfm. This can be accomplished by providing a supply fan to each corridor (Figure 22). This supply air can be tempered by mixing with the air in the corridor. The supply air serves to pressurize the corridor. Corridor conditioning is typically provided at corridor ends (Figure 23).

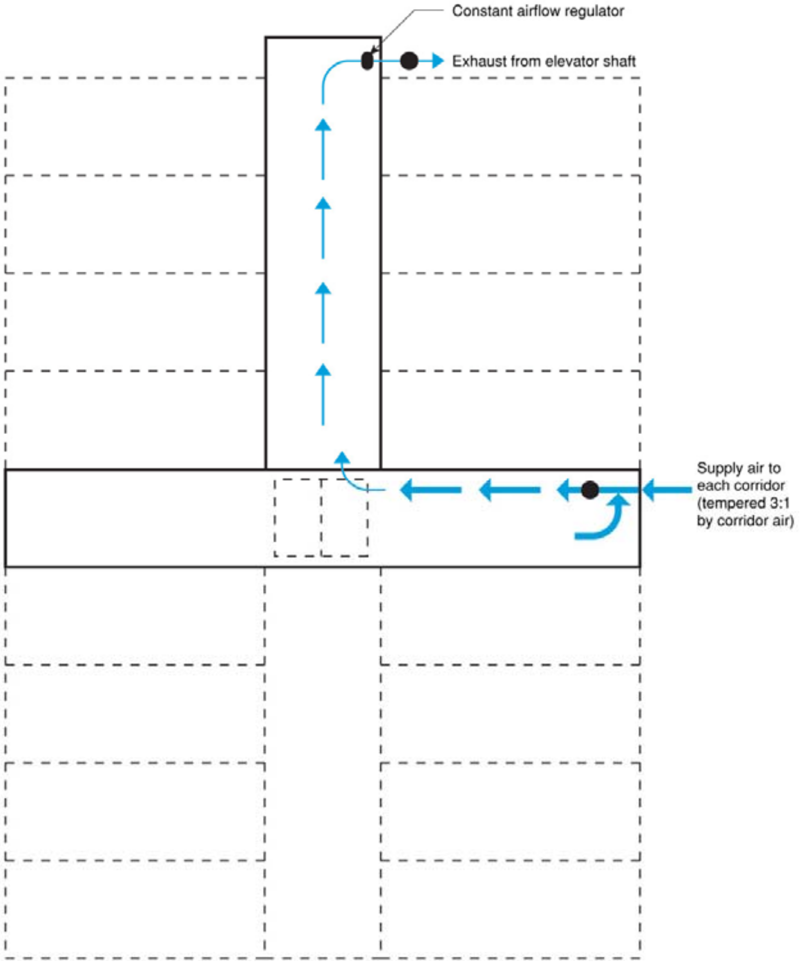


Figure 22: Corridor supply fan

Figure 23: Corridor conditioning

Elevator shafts are typically depressurized with a roof top fan whose exhaust flow is controlled by a constant airflow regulator to compensate for seasonal stack effect variation. Supply air to the corridors is removed by exhaust air from the elevator shaft.

The model codes typically require elevator shafts to have a smoke and hot gas vent. This vent should have a motorized damper connected to the fire control system (Figure 24). This vent should be closed under typical operation to prevent uncontrolled airflow.

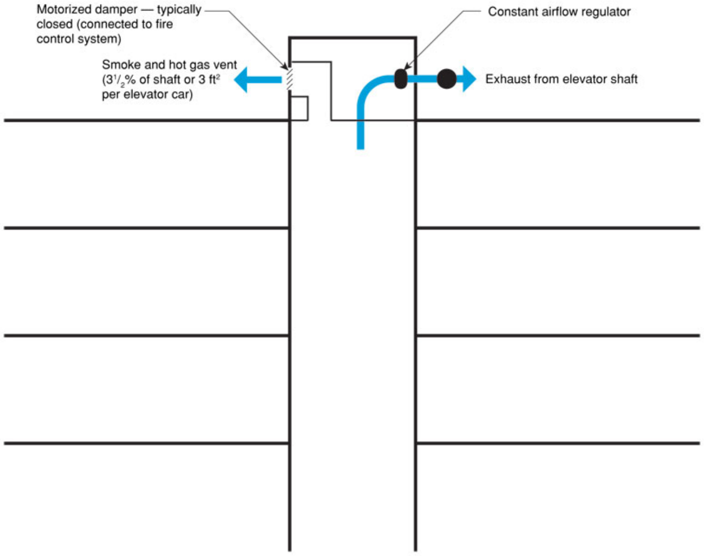


Figure 24: Elevator shaft smoke and hot gas vent

Individual corridor supply fans can be replaced by a central roof top system that supplies ventilation air to each corridor (Figure 25). In extreme cold or extreme hot-humid climates the central system is typically combined with a preconditioning unit (Figure 26).

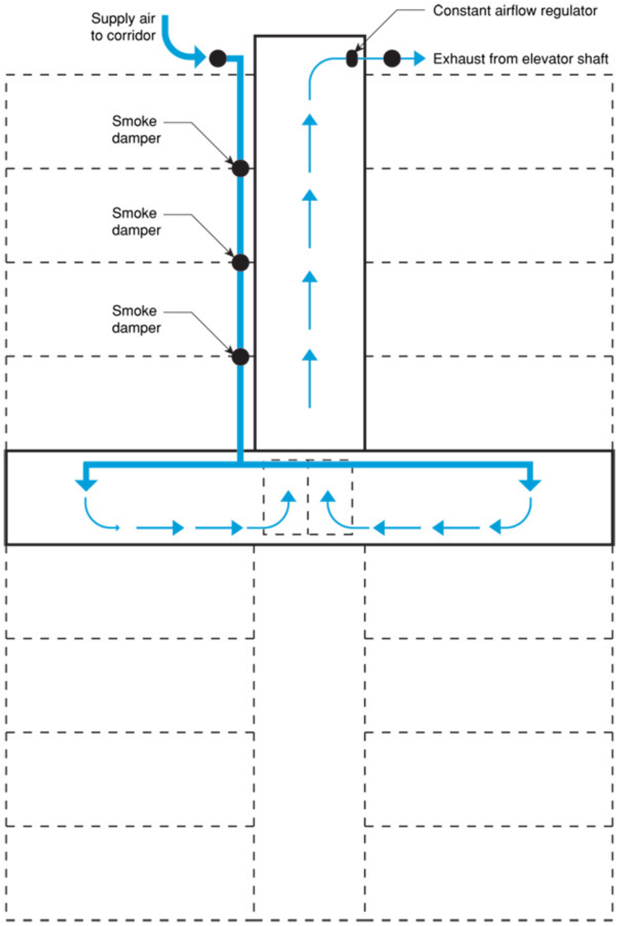


Figure 25: Corridor roof top supply system

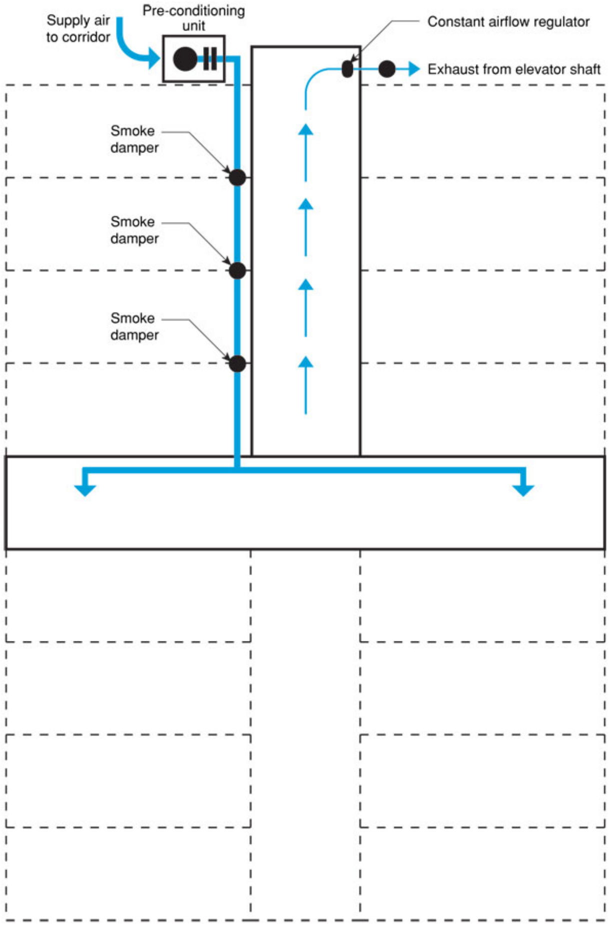


Figure 26: Pre-conditioning corridor supply

Trash chutes (Figure 27) should be depressurized to control odors as should trash rooms (Figure 28).

Figure 27: Trash chute – Should be maintained at a negative pressure

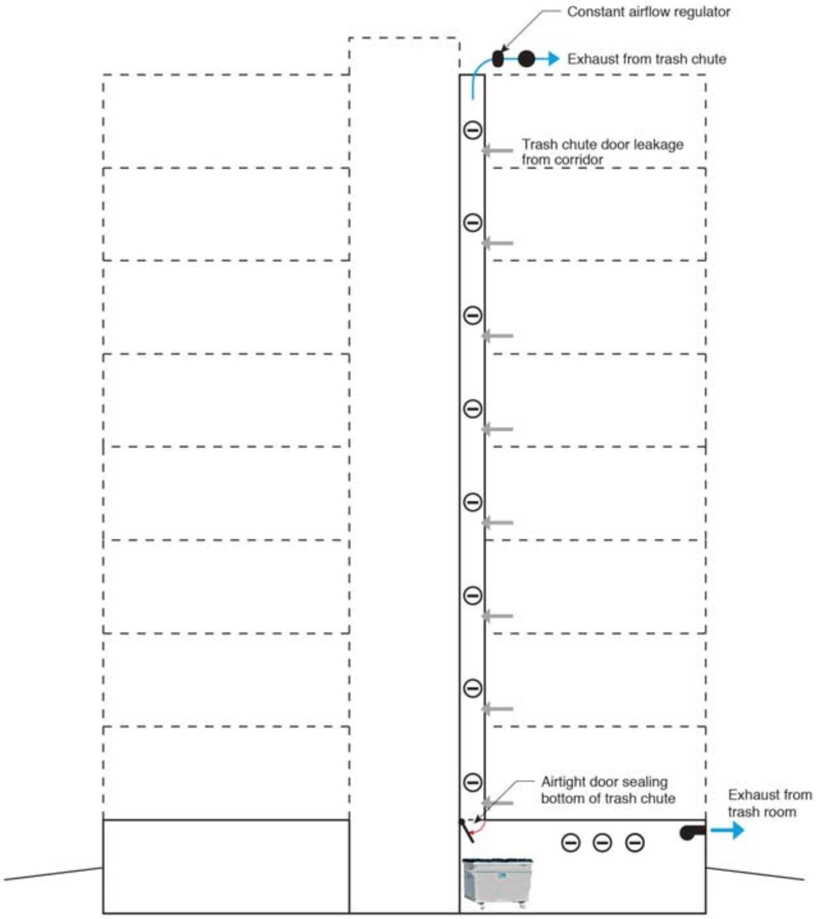


Figure 28: Trash chute pressure control

4 Measure Implementation

Various ventilation system options are presented. Each system is balanced and has provision for powered make-up air for vented kitchen range hoods and bathroom exhaust. Each system is designed to operate in a compartmentalized multifamily unit and with distributed heating and cooling systems or central systems where only hot water or chilled water or refrigerant is distributed, not air.

Climate Specific Factors

In warm-humid climates supplemental dehumidification is necessary in energy efficient homes where the sensible cooling load has been dramatically reduced (Rudd 2013). The issue is particularly acute in multifamily units ventilated at high ventilation rates such as those required by ASHRAE Standard 62.2 – 2013.

Field Inspection

Ventilation system flows should be verified. Control systems should be clearly identified. Operating instructions should be provided to the occupant. Scheduled maintenance guidance should be included in occupant information.

System 1: Forced Air – Outside Air to Return Side of Air Handler

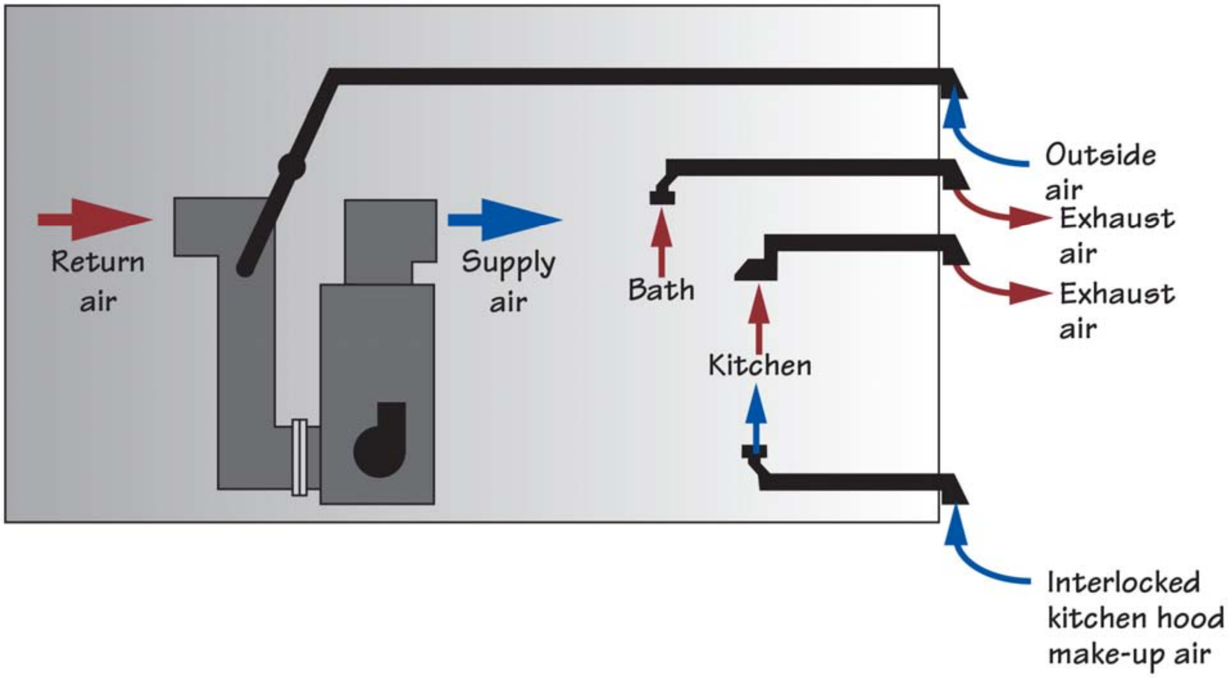


Figure 29: Forced air – Outside air to return to side of air handler

An outside air duct is connected to the return side of the air handler and the air handler operates continuously. The air handler is interlocked with a continuous bathroom exhaust fan. The ventilation rate set by ASHRAE Standard 62.2. The rate at which outside air is brought in through the outside air duct is matched by the exhaust rate of the bathroom exhaust. For example, if 45 cfm is supplied via the outside air duct then the bathroom fan exhausts continuously at a rate of 45 cfm. If two bathrooms are in the unit then the exhaust rate is split between the two bathrooms. A single exhaust fan is used with an exhaust grille in each bathroom.

A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate make-up air fan.

System 2: Forced Air – Outside Air to Return Side of Air Handler – Supplemental Dehumidification

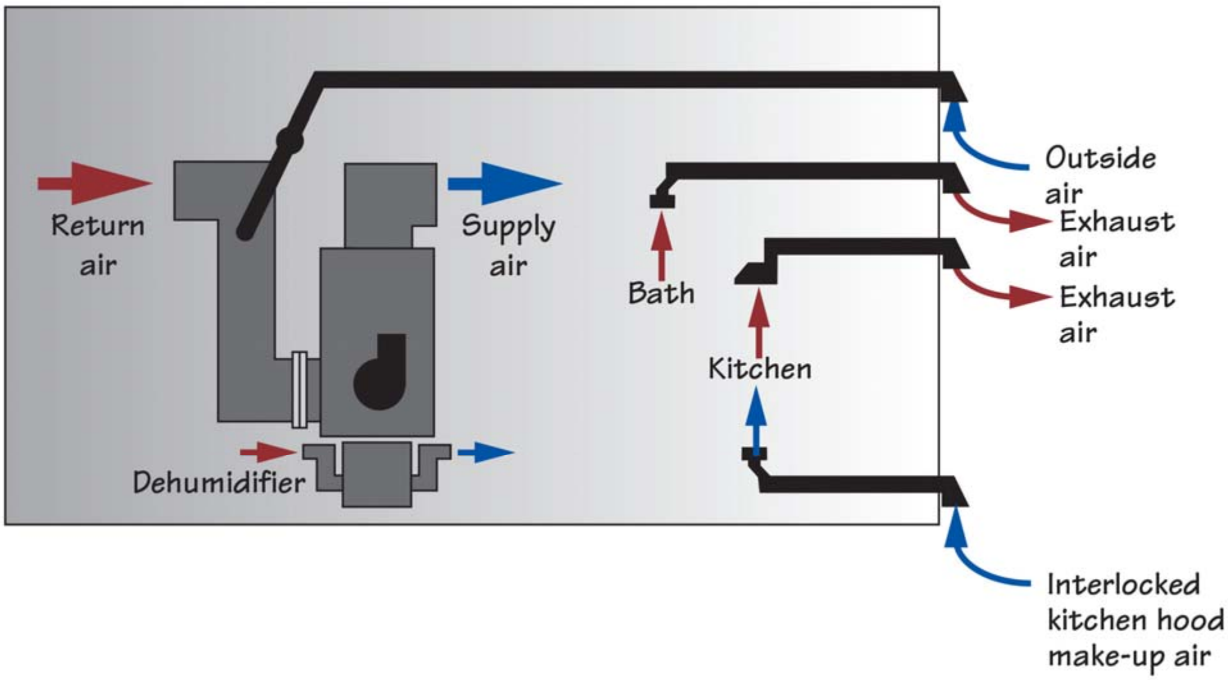


Figure 30: Forced air – Outside air to return to side of air handler – supplemental dehumidification

An outside air duct is connected to the return side of the air handler and the air handler operates continuously. The air handler is interlocked with a continuous bathroom exhaust fan. The ventilation rate set by ASHRAE Standard 62.2. The rate at which outside air is brought in through the outside air duct is matched by the exhaust rate of the bathroom exhaust. For example, if 45 cfm is supplied via the outside air duct then the bathroom fan exhausts continuously at a rate of 45 cfm. If two bathrooms are in the unit then the exhaust rate is split between the two bathrooms. A single exhaust fan is used with an exhaust grille in each bathroom.

A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate make-up air fan.

Supplemental dehumidification is provided by a dehumidifier.

System 3: Forced Air – Heat Recovery Ventilator/Energy Recovery Ventilator

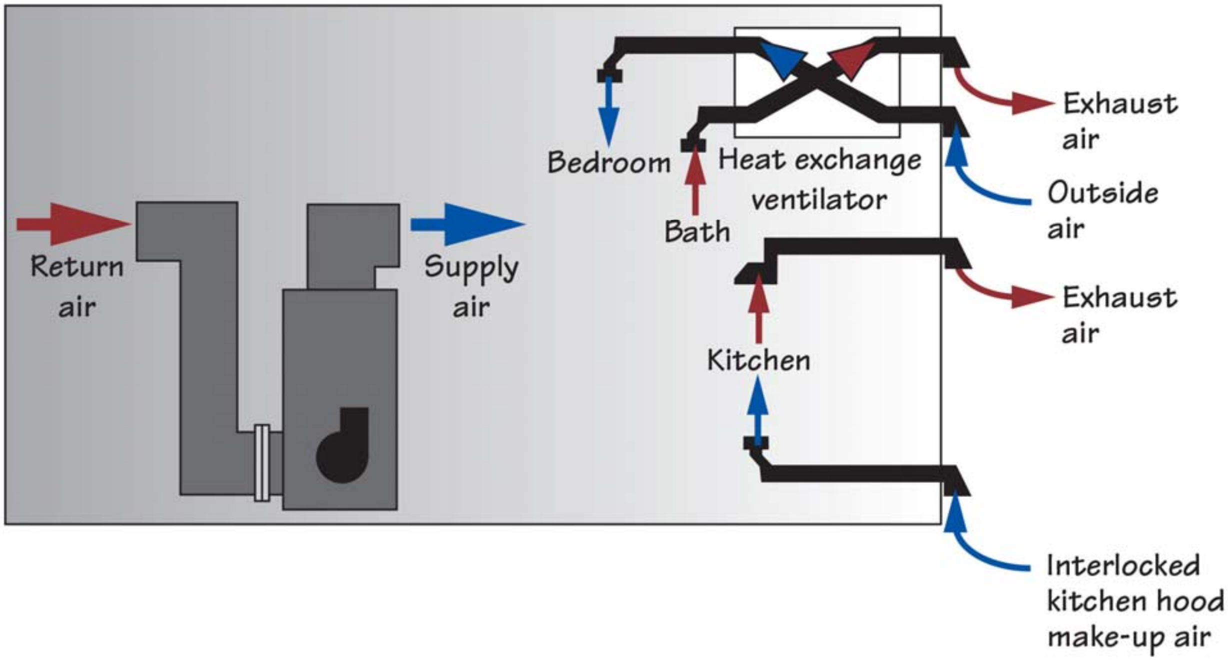


Figure 31: Forced air – Heat recovery ventilator/energy recovery ventilator

A fully-ducted heat recovery ventilator (HRV) or a fully-ducted energy recovery ventilator (ERV) provides balanced ventilation independent of the forced air conditioning system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s).

A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate make-up air fan.

System 4: Forced Air – Heat Recovery Ventilator/Energy Recovery Ventilator – Supplemental Dehumidification

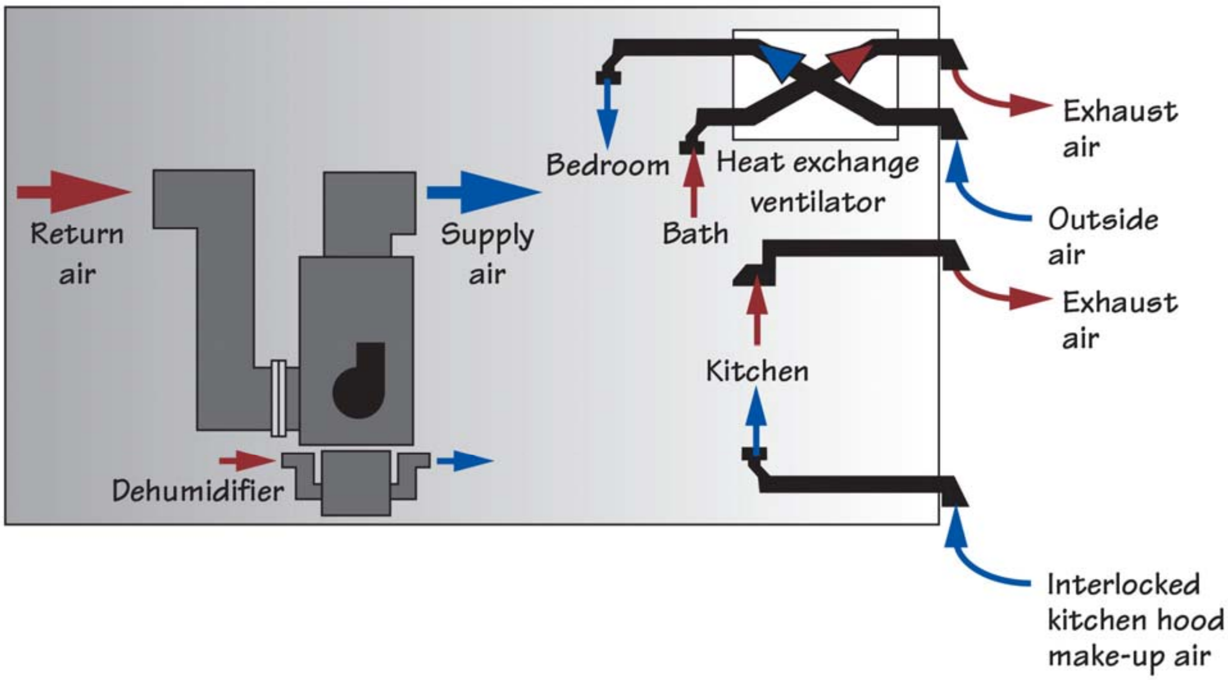


Figure 32: Forced air – Heat recovery ventilator/energy recovery ventilator – supplemental dehumidification

A fully-ducted heat recovery ventilator (HRV) or a fully-ducted energy recovery ventilator (ERV) provides balanced ventilation independent of the forced air conditioning system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s).

A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate make-up air fan.

Supplemental dehumidification is provided by a dehumidifier.

System 5: Packaged Terminal Heat Pump – Heat Recovery Ventilator/Energy Recovery Ventilator

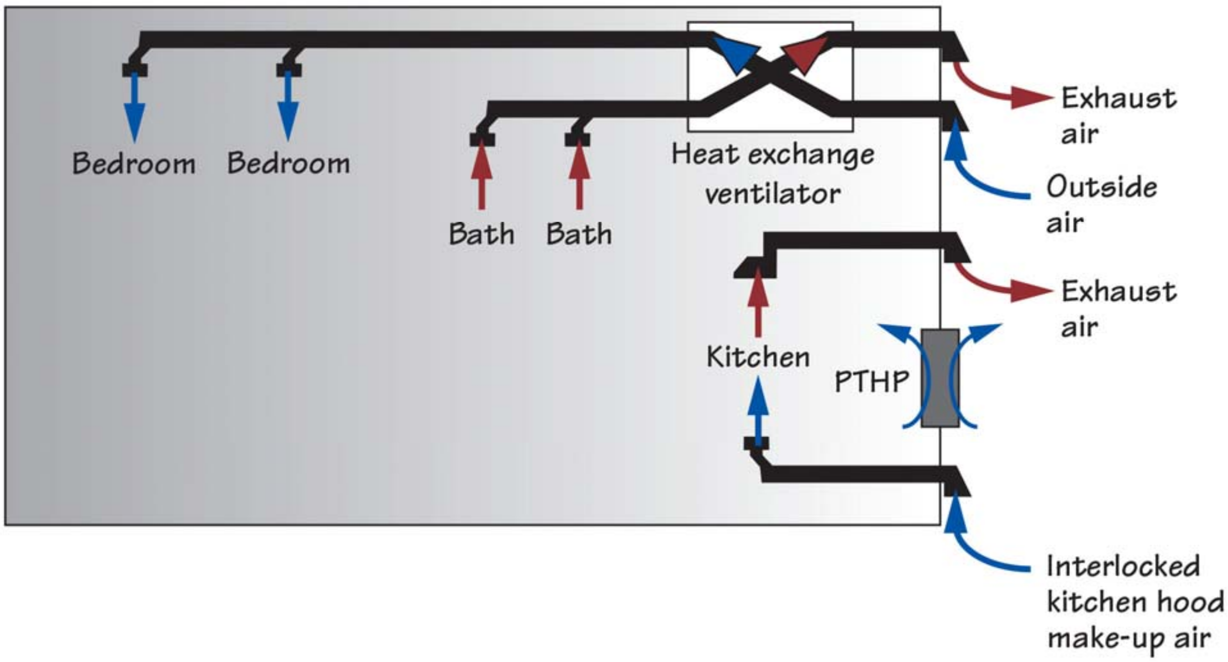


Figure 33: Packaged terminal heat pump – Heat recovery ventilator/energy recovery ventilator

A fully-ducted heat recovery ventilator (HRV) or a fully-ducted energy recovery ventilator (ERV) provides balanced ventilation independent of the packaged terminal heat pump (PTHP) conditioning system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s).

A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate make-up air fan.

System 6: Packaged Terminal Heat Pump – Heat Recovery Ventilator/Energy Recovery Ventilator – Supplemental Dehumidification

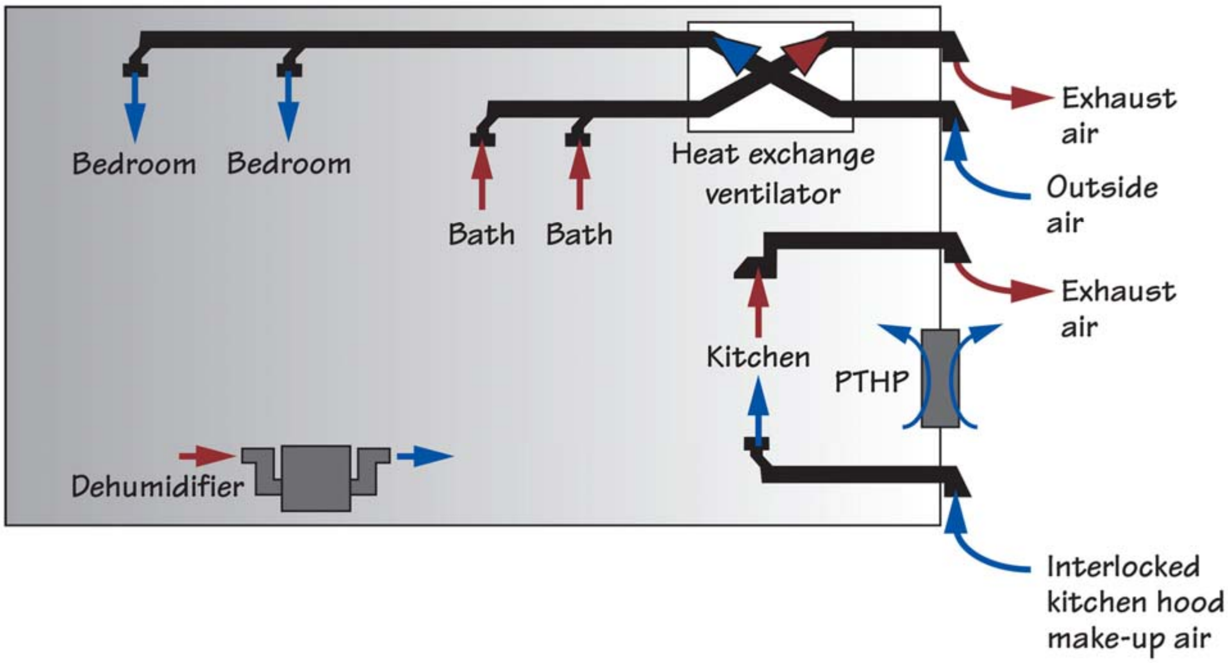


Figure 34: Packaged terminal heat pump – Heat recovery ventilator/energy recovery ventilator – supplemental dehumidification

A fully-ducted heat recovery ventilator (HRV) or a fully-ducted energy recovery ventilator (ERV) provides balanced ventilation independent of the packaged terminal heat pump (PTHP) conditioning system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s).

A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate make-up air fan.

Supplemental dehumidification is provided by a dehumidifier.

System 7: Radiant Heating – Heat Recovery Ventilator/Energy Recovery Ventilator

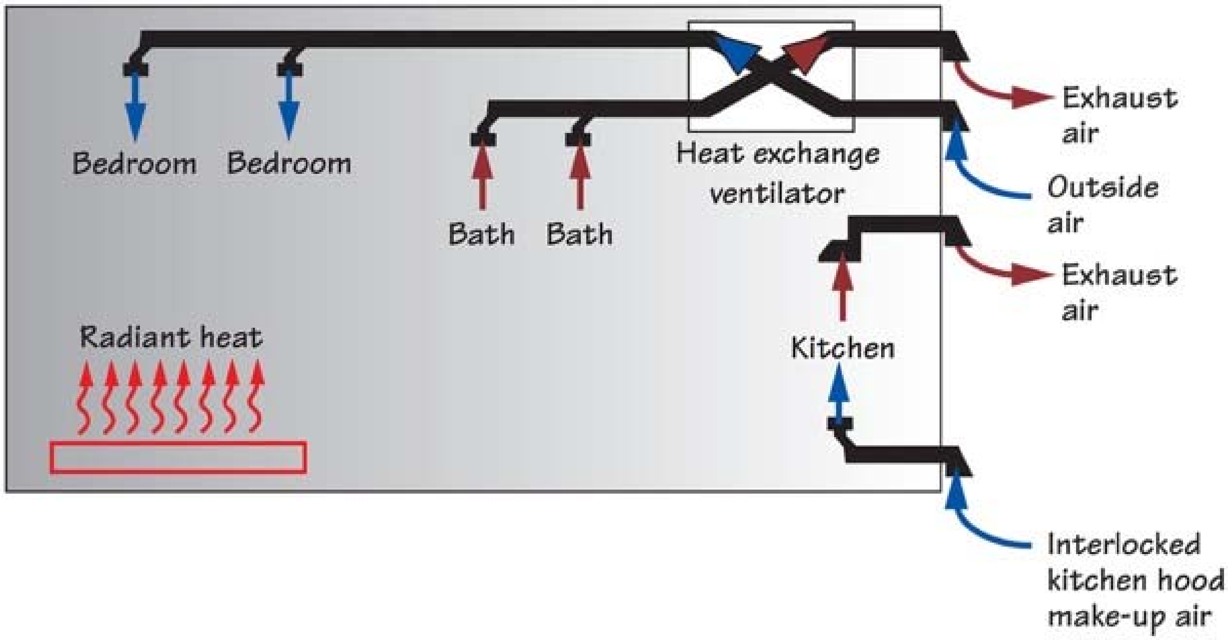


Figure 35: Radiant heating – Heat recovery ventilator/energy recovery ventilator

A fully-ducted heat recovery ventilator (HRV) or a fully-ducted energy recovery ventilator (ERV) provides balanced ventilation. Heating is provided by a radiant heating system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s).

A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate make-up air fan.

5 Verification Procedures and Tests

Ventilation system flow rate should be verified to be compliant with design. Control system operation should be verified.

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About this Report

This report was prepared with the cooperation of the U.S. Department of Energy's Building America Program.

About the Authors

Joseph Lstiburek, Ph.D., P.Eng., ASHRAE Fellow, is a principal of Building Science Corporation. Dr. Lstiburek has been a licensed Professional Engineer in the Province of Ontario since 1982 and is an ASHRAE Fellow. He is also an Adjunct Professor of Building Science at the University of Toronto. He has over thirty years of experience in design, construction, investigation, and building science research. Through the Department of Energy's Building America program, Dr. Lstiburek has forged partnerships with designers, builders, developers, materials suppliers and equipment manufacturers to build higher performance buildings across the U.S.

Direct all correspondence to: Building Science Corproation, 3 Lan Drive, Suite 102, Westford, MA 01886.

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